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(54) Hexagon Socket Head Bolt

(57) A hexagon socket head bolt has a hexagon socket (12) which is defined by inwardly convex circular arcs with a radius R of curvature given by

$$R=\frac{1}{12C}(S^2-6SC-3C^2)$$

[S: width across flats of a hexagon wrench key 14, B: width across flats of the hexagon socket, C: clearance (C=B−S)]. The periphery of the hexagon socket (12) is provided with tapered chamfers (16) formed of inwardly convex circular arcs with a radius R′ of curvature given by R′<R. Moreover, the bottom of the hexagon socket (12) has an upwardly convex surface.

FIG. 1

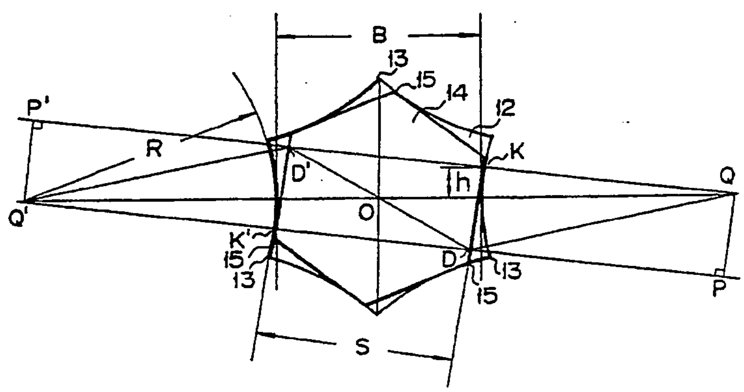
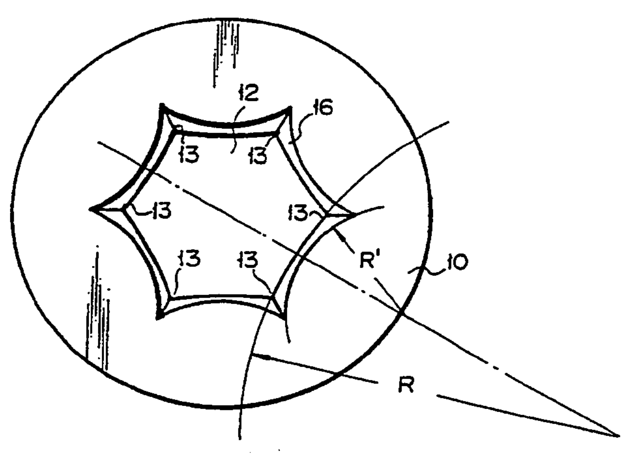


FIG. 3



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

FIG. 1

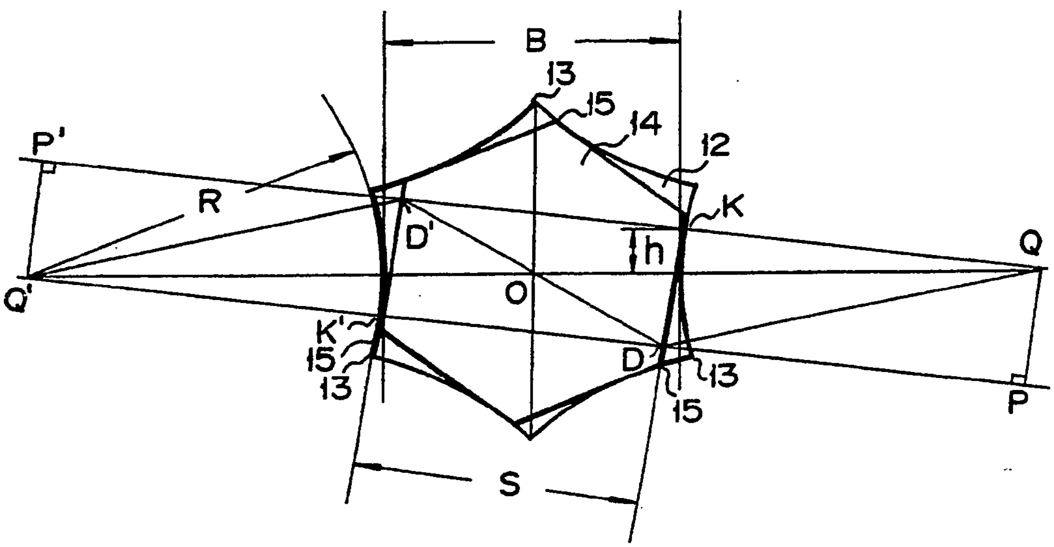


FIG. 2A

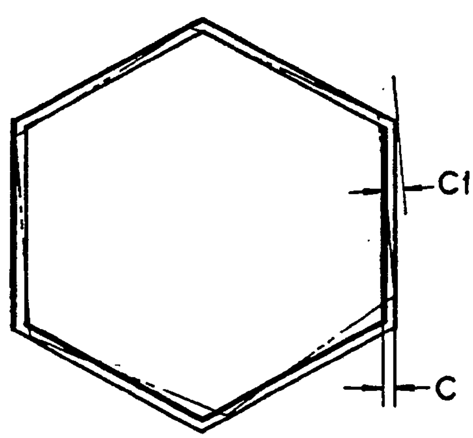


FIG. 2B

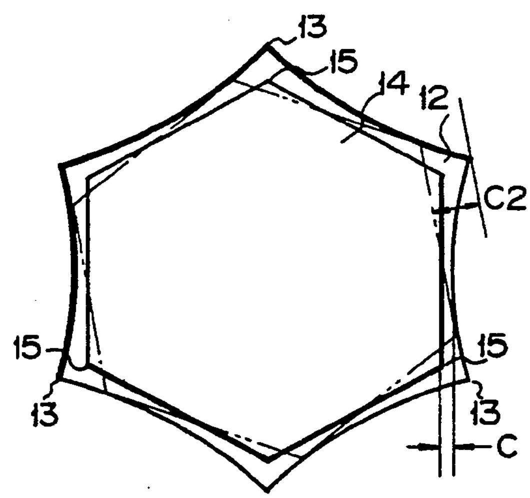


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FIG. 3

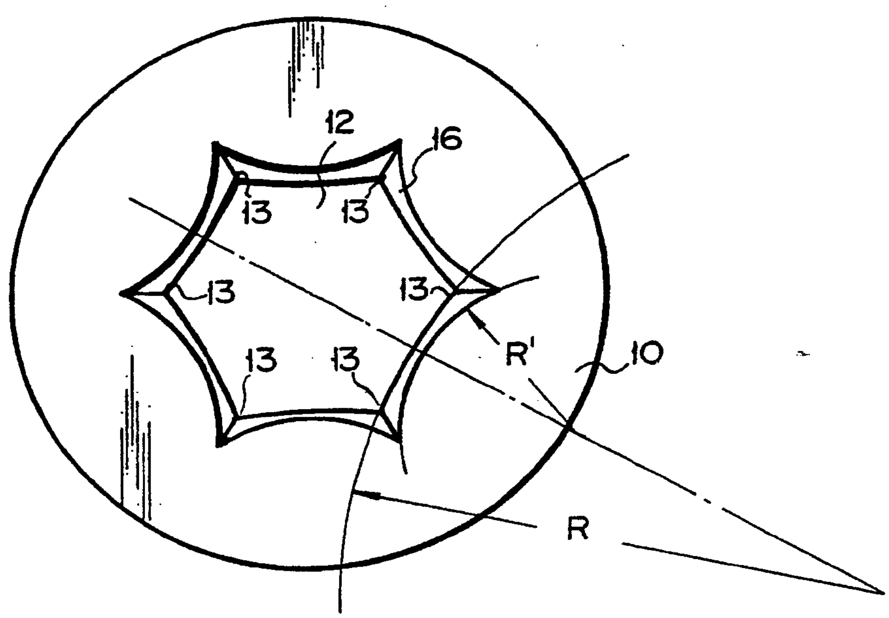

FIG. 4

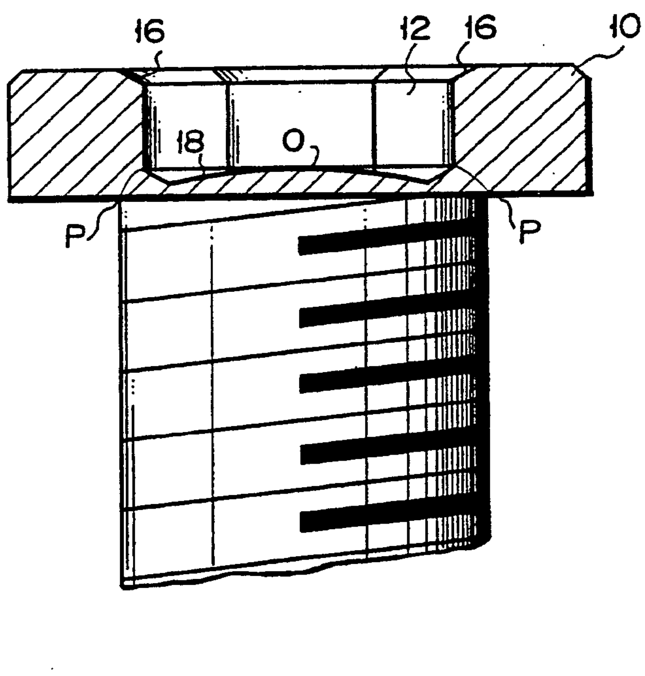

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FIG. 5A

FIG. 5B

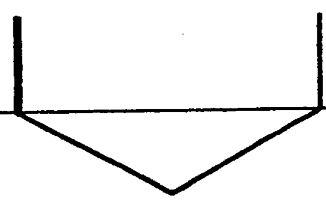


FIG. 5C

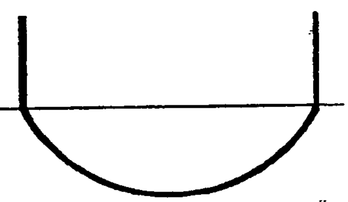
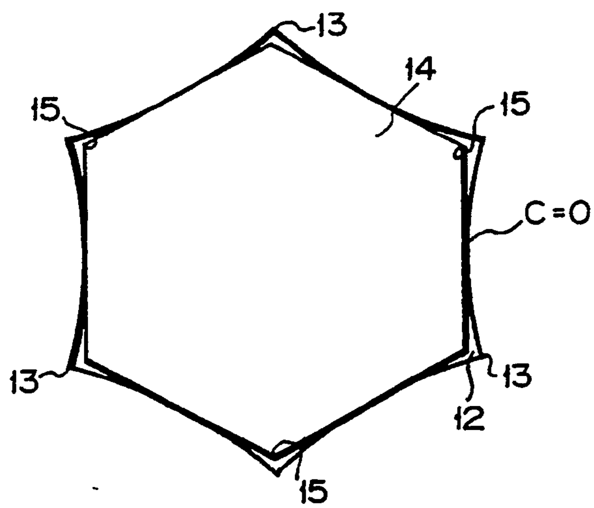


FIG. 6



SPECIFICATION

Hexagon S cket Head Bolt

This invention relates to a bolt, more particularly to a hexagon socket head bolt.

In various industrial fields including electric appliances and automobile industries, cross recessed head screws and slotted head screws are generally used as coupling means. Low-carbon steel rods generally formed of mild steel are used for these screws. Recesses or slots on the heads of the screws are formed under pressure by using a two-stage forming machine. Thus, capable of being easily formed of cheap low-carbon steel rods by only two heading processes, the cross recessed head screws and slotted head screws can be produced at very low cost, and are enjoying popularity. When the tip of a screwdriver is fitted in the head recess or slot of such screw and turned, however, the screwdriver may be caused to lift or slip off the recess by reaction force to push back the screwdriver outwardly because the tip of the screwdriver is tapered. This means a lack of operating efficiency. When the screwdriver is turned to transmit torque to the screw, moreover, it is two-dimensionally in point contact with the head recess to apply great torque locally to side walls defining the recess, so that there will be caused stress concentration, possibly damaging the screwdriver and the side walls of the head recess. Thus, the cross recessed head screws and slotted head screws cannot stand large.

For a hexagon socket head bolt, on the other hand, there is generally used as a screwdriver a hexagon wrench key without taper. When the hexagon wrench key is fitted in the hexagon socket of the bolt, it is securely held by the socket. Therefore, great tightening torque can be applied to the hexagon wrench key without causing the wrench key to lift or slip off the socket when the wrench key is turned. In order to meet the high-torque transmission of the hexagon wrench key, the hexagon socket head bolt is made of alloy steel with high mechanical strength. Alloy steel, however, is much more expensive than low-carbon steel. In order to prevent the hexagon wrench key from slipping off the hexagon socket and to ensure high-torque transmission, the depth of the socket is maximized, so that the bolt head cannot help being thick. Accordingly, the deep hexagon socket, thick head, and hard alloy steel material are the absolute requirement for the hexagon socket head bolt. Therefore, the hexagon socket cannot be formed by two heading processes, usually requiring three or more heading processes. Thus, the prior art hexagon socket head bolt cannot be produced at low cost because it uses expensive alloy steel and requires three or more heading processes.

Further, the hexagon socket head bolt and the hexagon wrench key to engage the bolt are standardized by industrial standards such as the International Organization for Standardization (ISO) and the Japanese Industrial Standards (JIS). The width B across flats of the hexagon socket is defined by the positive tolerance of the standard value, while the width S across flats of the hexagon wrench key is defined by the zero or negative tolerance of the standard value. Hereupon, if the hexagon wrench key is fitted in the hexagon socket with a similar cross section, there will naturally be created a parallel gap of size ranging from the maximum clearance to the minimum. When the hexagon wrench key is fitted in the hexagon socket and turned, there will be caused linear contact between them along the depth direction of the hexagon socket, so that the corners of the hexagon wrench key will be pressed against the side walls of the hexagon socket to round or crush the corners of the wrench key and/or socket. Thus, the life of the hexagon wrench key will be shortened, and the high-torque transmission will practically be impossible. Naturally, if the clearance between the hexagon socket and the hexagon wrench key is eliminated, entire surface contact can be obtained and the aforesaid trouble due to the linear contact can be eliminated. Considering the ease of engagement as well as the reduction of cost by mass production, however, the existence of the clearance is a vital necessity, and the clearance cannot be reduced to zero in the prior art hexagon socket head bolt.

This invention is contrived in consideration of the aforementioned circumstances, and has an object to provide a hexagon socket head bolt premised on the use of a conventional hexagon wrench key and capable of low-cost production by two-stage heading processes.

In order to attain the above object, the hexagon socket head bolt of this invention has the following three technical features. First, according to this invention, a hexagon socket is defined by inwardly convex circular arcs with a given radius R of curvature enabling surface-contact engagement between a hexagon wrench key and the hexagon socket. Secondly, the arcuated periphery of the hexagon socket is provided with chamfers formed of inwardly convex circular arcs with a radius R′ of curvature (R>R′). Thirdly, the bottom of the hexagon socket has an upwardly convex surface.

The above and further objects and novel features of the invention will more fully appear from the following detailed description when the same is read in connection with the accompanying drawing. It is to be expressly understood, however, that the drawing is for purpose of illustration only and is not intended as a definition of the limits of the invention.

This invention can be more fully understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

Fig. 1 is an analytical diagram for determining the radius of curvature of circular arcs forming a hexagon socket of a hexagon socket head bolt according to this invention;

Figs. 2A and 2B are schematic plan views showing the engagement between a hexagon wrench

key and hexagon sockets of a prior art hexagon socket head bolt and the bolt of the invention, respectively;

Figs. 3 and 4 are a plan view and a partially broken front view of a hexagon socket head bolt according to an embodiment of this invention, respectively;

Figs. 5A to 5C are diagrams for comparing the depth of socket bottom between the structure of the invention and prior art structures; and

Fig. 6 is a schematic plan view similar to Fig. 2B showing another embodiment of the invention.

Now there will be described embodiment of this invention in detail with reference to the accompanying drawings.

In order to enable transmission of great torque through the engagement between a hexagon socket head bolt 10 and a conventional hexagon wrench key 14, a hexagon socket 12 is defined by inwardly convex circular arcs with a suitable radius of curvature to provide surface contact. The optimum radius of curvature of the hexagon socket 12 may be obtained in the following manner.

In Fig. 1, symbols are defined as follows:

K, K′: Contact points between the hexagon socket 12 and the hexagon wrench key 14,
$W=KK'=DD'$: Distance between the contact points,
S: Width across flats of the hexagon wrench key 14,
B: Width across flats of the hexagon socket 12,
R: Radius of curvature given to the hexagon socket 12,
$C=B-S$: Clearance between the hexagon socket 12 and the hexagon wrench key 14.

Other symbols may easily be understood from Fig. 1 without any definition. Referring now to Fig. 1, the radius R will be determined geometrically.

First, we have:

$$\begin{aligned}QQ'^2&=Q'P^2+PQ^2=(Q'D+DP)^2+PQ^2\\&=Q'D^2+2Q'D\,.\,DP+DP^2+PQ^2\\&=Q'D^2+2Q'D\,.\,DP+QD^2=QD'^2+2Q'D\,.\,DP+QD^2\end{aligned}$$

and

$$\begin{aligned}D'D^2&=(Q'D-Q'K')^2+D'K'^2=Q'D^2-2Q'D\,.\,Q'K'+Q'K'^2+D'K'^2=Q'D^2-2Q'D\,.\,Q'K'+Q'D'^2\\&=Q'D^2-2Q'D\,.\,DP+QD^2=QD'^2-2QD'\,.\,DP+QD^2\end{aligned}$$

so we obtain

$$QQ'^2+D'D^2=2(QD^2+QD'^2).$$

Substituting for

$$\begin{aligned}QQ'^2&=(2R+B)^2\\D'D^2&=W^2\\QD^2&=R^2+W^2-S^2\\QD'^2&=(R+S)^2,\end{aligned}$$

we obtain

$$\begin{aligned}&4R^2+4RB+B^2+W^2=2(R^2+W^2-S^2+R^2+2RS+S^2)=4R^2+2W^2+4RS\\&4R(B-S)=W^2-B^2\end{aligned}$$

Thus, R is given by

$$R=\frac{1}{4(B-S)}(W^2-B^2)=\frac{1}{4C}\{W^2-(S+C)^2\} \qquad (1)$$

While the width S across flats of the hexagon wrench key 14, the width B across flats of the hexagon socket 12, and the clearance C are fixed values given by the industrial standard, the distance W between the contact points can be selected freely. The greater the distance W, the greater the radius R of curvature will be. The greater radius R of curvature will provide greater contact length and greater contact area, thereby preventing stress concentration, that is, dispersing the stress. As a result, the contact stress is reduced to enable transmission of large tightening torque. The distance W between the contact points is maximized when the contact points K and K′ coincide with the corners 15 of the hexagon wrench key 14. Since we have $K'KD=60°$, the maximum Wmax of the distance W is given by

$$Wmax=\frac{2S}{\sqrt{3}} \qquad (2)$$

Substituting th value of W of eg. (2) into eg. (1), therefore, the optimum radius R of curvature may be obtained as follows:

$$R=\frac{1}{4C}\left[\frac{4S^2}{3}-(S^2+2SC+C^2)\right]$$

$$=\frac{1}{12C}(4S^2-3S^2-6SC-3C^2)$$

$$=\frac{1}{12C}(S^2-6SC-3C^2)$$

Then, if the contact points K and K′ coincide with the corners 15 of the hexagon wrench key 14, there will be caused undesired point contact in two dimensions (linear contact in three dimensions). Practically, therefore, the contact points K and K′ must be located off the corners 15 of the hexagon wrench key 14 but as near thereto as possible. However, it is to be understood that the optimum radius R of curvature may theoretically be obtained by supposing a case where the contact points K and K′ are coincident with the corners 15.

With the hexagon socket defined by the inwardly convex circular arcs with the optimum radius of curvature,

$$R=\frac{1}{12C}(S^2-6SC-3C^2)$$

there may be obtained surface contact to provide the maximum contact area and the minimum contact stress. Thus, great torque may be transmitted to provide sufficient tightening torque without the stress concentration on the corners 15 of the hexagon wrench key 14 and without damaging the corners 15 or the side walls of the hexagon socket 12.

In the engagement between the hexagon socket of a prior art hexagon socket head bolt and the hexagon wrench key, as shown in Fig. 2A, the wrench key can be fitted in the hexagon socket when the clearance C is obtained, as long as the wrench key is within a distance C1 from each corner 13 of the hexagon socket. According to this invention, on the other hand, since the hexagon socket 12 is defined by the inwardly convex circular arcs with the radius R of curvature, the distance between the side walls of the hexagon socket and the hexagon wrench key is not uniform, having a maximum between their respective corners 13 and 15 and a minimum in the center of their sides, as shown in Fig. 2B. The hexagon wrench key 14 may be fitted in the hexagon socket 12 as long as it is within a distance C2 from the corner 13 of the hexagon socket 12. As may be seen from Fig. 2B, the distance C2 is considerably greater than the distance C1 for the prior art hexagon socket head bolt. In this invention, therefore, the fit tolerance for the hexagon wrench key 14 to be fitted in the hexagon socket 12 increases to enable easier engagement between the wrench key and the socket, thereby improving the working efficiency, as compared with the conventional case.

In the hexagon socket head bolt 10 of this invention, as shown in Figs. 3 and 4, tapered chamfers 16 formed of inwardly convex circular arcs with a radius R′ of curvature (R>R′) extend along the peripheral edge of the hexagon socket 12. With these chamfers 16, the distance between each side of the hexagon socket with the radius R of curvature and each chamfered edge with the radius R′ of curvature has a minimum in the center of each side and a maximum at each end. Each end portion of the chamfered edge makes an acute angle with one end portion of each adjacent edge, thereby forming a peculiar star shape along the peripheral edge of the hexagon socket. In actual field work to screw a number of hexagon socket head bolts into predetermined positions, it is very important to recognize the outline of the hexagon socket of each bolt. If the outline of the hexagon socket can be recognized at a glance, the hexagon wrench key will be able to be fitted in the hexagon socket with accuracy and speed to improve the efficiency of the tightening work. Further, accurate engagement between the hexagon wr nch key and hexagon socket will decrease damages on them, especially the corners of the wrench key. According to this invention, the existence of the tapered chamfers 16 provides th peculiar shape around the hexagon socket, thereby enabling to recognize the outline of the socket at a glance. Thus, the fitting of the hexagon wrench key 14 in the hexagon socket 12 is facilitated to increase working efficiency. Moreover, the corners 15 of the hexagon wrench key 14 are protected from damages, and the lifework of the hexagon wrench key will increase to enable transmission of large torque in a long period of time. Since a bolt heading punch is necessarily provided with a flange for chamfering at the neck, the neck or the most breadble portion of th punch is

strengthened to allow great pressure to be applied to the punch. Thus, the bolt heading processes are simplified to increase the lifework of the punch, ther by enabling continuous mass production of hexagon socket head bolts with use of the same punch and improving the productivity.

As shown in Fig. 4, moreover, the bottom of the hexagon socket of the hexagon socket head bolt has an upwardly convex curved surface 18. As seen from Figs. 5A to 5C, the bottom portion of the hexagon socket 12 according to the invention (Fig. 5A) can be formed much shallower than the bottom portions of the hexagon sockets of conventional hexagon socket head bolts as shown in Figs. 5B and 5C, so that the head of the hexagon socket head bolt of the invention can be reduced in thickness. By forming the curved surface 18 so that the apex O of the curved surface 18 may be at the same level with the lowest point P of each side wall of the hexagon socket, the hexagon wrench key 14 can be inserted in the hexagon socket to the depth of the points O and P. Since the hexagon wrench key 14 can reach the lowest possible point to secure sufficient fit length between the hexagon socket and the wrench key despite the shallowness of the socket, it will be prevented from falling to ensure satisfactory transmission of large torque.

By forming each corner of the hexagon socket 12 from an outwardly convex circular arc, each corner of a bolt heading punch used can also be formed of a circular arc, requiring no sharp-edged portions for engagement. Accordingly, the corners of the punch can be protected against abrasion to prolong the lifework of the punch. According to this invention, moreover, the hexagon socket is defined by inwardly convex circular arcs with the radius R of curvature, so that a sufficient space will be left between the corners 13 of the hexagon socket and the corners 15 of the hexagon wrench key even though the clearance is zero. Thus, the hexagon wrench key 14 will be allowed to be fitted in the hexagon socket 12 despite the zero clearance. In the zero-clearance fitting, the hexagon wrench key 14 fits the hexagon socket 12 without any gap, and the wrench key is perfectly prevented from falling. Accordingly, the hexagon wrench key 14 and the hexagon socket 12 are fully guarded against damages, and large torque may be transmitted from the wrench key to the hexagon socket head bolt 10 with smoothness and high efficiency.

According to this invention, as described above, entire surface-contact fitting is provided by defining the hexagon socket by inwardly convex circular arcs with the radius R of curvature given by

$$R=\frac{1}{12C}(S^2-6SC-3C^2)$$

so that the contact area is increased to reduce the contact stress. Accordingly, inexpensive hexagon socket head bolts can be produced by few bolt heading processes with use of cheap low-carbon steel instead of expensive, hard alloy steel as the material. Further, the outline of the hexagon socket can be recognized at a glance through the tapered chamfers around the sockets formed of inwardly convex circular arcs with the radius R′ of curvature ($R>R'$). As a result, the hexagon wrench key can accurately be fitted in the hexagon socket, and damages on the wrench key and socket, especially damages on the corners of the wrench key, can be prevented. Accordingly, torque applied to the hexagon wrench key can efficiently be transmitted to the hexagon socket head bolt to provide sufficient tightening torque without any large torque on the wrench key. Therefore, it is unnecessary to use hard alloy steel as the material for the hexagon socket head bolt. Further, the flange for chamfering is necessarily be formed at the neck of the bolt heading punch to strengthen the punch. In consequence, considerably high pressure can be applied to the punch, so that the bolt heading processes can be simplified for low-cost production of hexagon socket head bolts. Since the bottom of the hexagon socket has an upwardly convex curved surface, the hexagon socket can be made relatively shallow. Therefore, the bolt head can be formed relatively thin, contributing to the simplification of the bolt heading processes. Despite its shallowness, the hexagon socket can securely hold the hexagon wrench key without reducing the efficiency of torque transmission, and it is unnecessary to use alloy steel for the hexagon socket head bolt.

Thus, the three technical features of this invention are each conducive to the simplification of the bolt heading processes and/or the changeover of material to low-carbon steel. Moreover, these three features are combined with one another to enable such simplification and changeover. In consequence, the hexagon socket head bolt can be produced from low-carbon steel by two bolt heading processes at low cost.

Since the hexagon socket is defined by inwardly convex circular arcs with the radius R of curvature, the clearance between the hexagon wrench key and the socket is not uniform, having a maximum between th ir respective corners and a minimum between the centers of their respective sides. Accordingly, the fitting of the hexagon wrench key becomes greater to facilitate the engagement between the wrench key and socket, thereby increasing the working efficiency. If necessary, the clearance can be made zero. Furthermore, the peripheral edge of the hexagon socket is provided with the tapered chamfers formed of inwardly convex circular arcs with the radius R′ of curvature given by $R'<R$, for easy recognition of the outline thereof, so that the fitting of the wrench key itself may be

facilitated. As a result, the combination of these features leads to a remarkably increase of working efficiency.

In this invention, furthermore, the bolt head as well as the bolt itself can be of any shape provided the bolt is a hexagon socket head bolt. Namely, this invention covers bolt or screw heads of various shapes including round, cylinder, fillister, pan, oval countersunk, flat and bind heads, as well as bolts or screws of various types including machine screws, wood screws, tapping screws, setscrews, etc.

Claims

1. A hexagon socket head bolt with a hexagon socket head, characterized in that a hexagon socket is defined by inwardly convex circular arcs with a radius R of curvature given by

$$R=\frac{1}{12C}(S^2-6SC-3C^2)$$

[S: width across flats of a hexagon wrench key, B: width across flats of the hexagon socket, C: clearance (C=B—S)] that the periphery of said hexagon socket has tapered chamfers formed of inwardly convex circular arcs with a radius R′ of curvature given by R′<R, and that the bottom of said hexagon socket has an upwardly convex surface.

2. A hexagon socket head bolt according to claim 1, characterized in that the clearance (C=B—S) is zero.

3. A hexagon socket head bolt according to claim 1 or 2, characterized in that the apex of the curved bottom surface of said hexagon socket is on the same level with the lower edge of each side wall of said socket.

4. A hexagon socket head bolt, substantially as hereinbefore described with reference to Figs. 1, 2B, 3, 4, 5A and 6 of the accompanying drawings.

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